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# MANUAL OF AGRICULTURE

## FOR THE COMMON SCHOOLS OF ILLINOIS

PREPARED BY

D. O. BARTO, B.S.

INSTRUCTOR IN AGRICULTURE, COLLEGE OF AGRICULTURE,
UNIVERSITY OF ILLINOIS

D. APPLETON AND COMPANY
NEW YORK CHICAGO
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# MANUAL OF AGRICULTURE FOR THE COMMON SCHOOLS OF ILLINOIS

## INTRODUCTION

Because the experiences that come to the country child are drawn so largely from Nature's laboratory and deal with the wonderful mysteries of life, with beginnings, and with things that are young and growing and constantly changing, and for that reason peculiarly fascinating for boys and girls, the study of agriculture is especially adapted to school work. That is, it is especially adapted to make intelligent and efficient men and women of the pupils by training them to think.

The writer has tried to outline in this little guide sets of studies and exercises in agriculture on topics of general importance and interest to farmers in all sections of Illinois and to make treatment of each topic sufficiently complete to give a fairly comprehensive idea of the main facts and of their relations to other problems in agriculture. Especially has the writer tried to make all statements in the presentation of each topic accord strictly with the teachings of the highest authorities in agricultural science.

Teachers frequently underestimate the pupil's ability to comprehend and to think. It is necessary in teaching agriculture, even in its simplest lessons, to use terms and principles that belong to other sciences, such as botany, physics, chemistry, physiology, and zoology. May there not be a great advantage for the child to make his first acquaintance with these sciences in a field where he is somewhat at home?

The subjects presented in this outline have been selected because of their generally recognized importance in the field of agriculture, and because they deal with matters of common interest in all parts of the state. As the work grows, and the preparation of teachers in the subject becomes more extended, the field will naturally widen, and schools will properly include in their courses those topics that are related to the particular agricultural interests of their section of the country.

There is probably more work outlined here than any school can accomplish in a one-year course. The schools of a county, or of a smaller area, with the coöperation of their County Superintendent, might agree at the beginning of the year on the part of the work they would attempt to cover and the order in which they would take up the exercises; then, by holding joint meetings occasionally and reporting and discussing the results of their experiments, the work would gain much in interest and value for all.

It is not intended that the order in which the exercises are given in this outline shall be closely followed in practice. The present arrangement makes it possible to present each division of the subject by itself and in more natural and logical sequence than would be possible were the exercises arranged in groups suited to each month in the school year. Everyone will readily understand that certain exercises, like several of those relating to corn, must come at the beginning of the school year in the fall. Others having to do with the preparation of plots and the planting of crops must be reserved for the work of April and May. Some of the work necessarily belongs to the summer months and must be planned either as *home work* or as *vacation school work*. But a large part of the exercises is laboratory work and can be done during any part of the year, particularly if some place be provided where things will not freeze at night.

All the work outlined here is real agriculture, as serious

as that taught in the colleges; but in the hands of competent teachers, it is no more difficult for the pupils to comprehend and perform than the other school work for the seventh and eighth grades. The course is not intended for pupils of the lower grades. They are too young and inexperienced to profit by it.

A list of agricultural books, bulletins, and other publications is given; and teachers are urged to read and use them as freely as time allows. Bulletins and circulars can be obtained simply by writing for them. Of course every teacher of the subject will own some good books on agriculture, and every school where it is taught should start a reference library of agricultural works.

# PART I

## STUDIES WITH THE SOIL

**What Agriculture Means.**—Ask a country boy or girl what agriculture is, and the answer doubtless will be: "Agriculture is the business of growing crops, of raising and feeding farm stock, of producing milk, perhaps of making butter and cheese from the milk." While agriculture includes many more things than these and is really a very complex business, the answer names what may be considered the *fundamental* things of agriculture; and the lessons and exercises in this little outline deal with this side of the business of agriculture.

**What Are the Essentials in Growing Crops?**—Again ask the boys and girls in the country what are the necessary things in the business of growing crops, and the answers will certainly be: "Land (soil) and seed." Implements and teams to be used in preparing the soil for planting the seed and in tilling the crops while they are growing and in harvesting them when they are mature will probably be included in most answers, but they will not be named, or thought of, first. Everybody knows, however, that crops cannot be grown without the use of soil and seed. That being the case, it is plain that the study of agriculture may well begin with a study of these two essentials, soil and seed.

**How Is the Soil Necessary to Growing Plants?**—We cannot think of fishes living anywhere except in the water. It is true that a plant may be made to grow in the water, where it has no contact with the soil, if some means be provided to hold it fast and support its stem; but this is because the water contains certain substances that it has dissolved out of the soil,

and which the plant can thus get. So really in this case the soil is as much a necessity to the plant as water is to fishes.

But what does the soil do for the plant? (A crop is only a group of the same kind of plants grown together, and we may study a single plant to learn the needs of the crop.) Has the soil more than one relation to the plant? Does it serve several needs? Let us begin our study of agriculture with the attempt to answer these points.

**The Soil Is the Natural Home of the Plant.**—By "natural home" is meant that situation where the individual, either animal or plant, finds those conditions and surroundings which it likes, which best satisfy its needs and help it develop to its fullest capacity.

The plant finds this situation in the soil. The roots spread through the soil, forcing their way between the particles, wrapping their delicate root-hairs about the separate grains of soil, thus securing the necessary anchorage and support for the whole plant, and absorbing from the soil certain food substances that the soil water has dissolved.

Besides anchoring it and providing a reservoir for water and a portion of the plant's food, the soil acts as a moderator of temperature. It absorbs the rays of heat from the sun and gradually gives up this warmth at night. There are other services, though these are the principal ones, which the soil performs for the plant.[1]

**What Is a Soil?**—I suppose you are saying: "The soil is dirt, ground, earth—everybody knows that." Well, let us try an experiment. Perhaps that will teach us something about soils that we have never thought of. We will call it:

### Exercise I

*What Constitutes a Soil?*—Get 3 flower pots or boxes that will hold about a quart and label them I, II, III. Fill I nearly

[1] The Principles of Agriculture, pp. 25, 26.

full of pure sand such as can be obtained along the shores of Lake Michigan. In II put earth that came from a depth of two or more feet below the surface. (You can get this where a cellar or a cistern is being dug.) Use the earth from the surface of a field or a garden to fill III. In each pot plant a grain of corn, a bean, and an oat grain. Treat the pots alike in respect to warmth, light, and watering.

Use only *pure rainwater* or distilled water to water them, as this contains no plant food which has been leached out of the ground. At first the plants will probably thrive equally well in each pot; for every little plant at first lives on the food its mother has packed about it in the seed. But in about a week this will be consumed, and each plant must find its food for itself from the material surrounding it. Do you notice a difference in the growth of the plants in the three pots? If you are using only pure sand in I, and in II material that came from some depth below the surface, and are watering them with pure rainwater, the plants in I and II will soon begin to die. They are *starving*. We said that a soil is the natural home of the plant because it supplies its needs. The materials in I and II are failing to do that. A difference between the materials in I and II and what was placed in III is that the earth in III is a mixture of finely ground rocks, which we call *mineral* or *inorganic matter*, and small bits of decaying plant and animal tissues. These latter are termed *organic matter*.

But in pots I and II there is no organic matter,—only the mineral substances that have come from the disintegration of rocks. Now certain parts of the food that a plant must have in order to make its full growth and mature its seeds come from the organic matter in the soil, called the *humus*, and other parts are derived from the mineral or inorganic substances. *A true soil, then, must always be a mixture of these two materials.*[1]

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[1] Soils, pp. 7, 26, 27.
The Principles of Agriculture, pp. 28–36.
The Soil, pp. 1–26.
Practical Agriculture, pp. 33–36.

## Exercise II

*Of What Are Soils Composed?*—Spread a teaspoonful of soil from each sample on sheets of white paper and carefully examine the particles of each. Notice that by far the greater portion of most of the samples is fine pieces of rock (sand), and that in all of them are many—more in some than in others—particles of rotting plant and animal matter and bits of roots and stems and leaves that are not yet much decayed.

Carefully weigh out an ounce of each kind of soil, put it into an iron spoon and heat red-hot for several minutes over a gas jet or on live coals. After cooling weigh the contents of the spoon again. There will be a loss in weight. A part of the soil has burned up. This part is called the *organic matter* of the soil and is vegetable and animal substance. As it decays it grows dark in color and forms what is called *humus*. The part of the soil in each sample that did not burn was made of rock, *inorganic matter*, or *mineral*. The soils should be perfectly dry before they are weighed into the spoon. Do all the samples of soils lose the same amount by weight in the burning? Which loses the greater weight, the dark garden soil or a sample of light colored soil? At least one of the samples should be taken from 20 to 40 inches below the surface. This layer is called *subsoil*. Samples can be procured from the side of a bank where a cellar or a ditch is being dug. Notice the difference in color between the two layers of soil, the *surface* and the *subsoil*. How do you account for the difference in color? Does the ounce of subsoil lose as much by burning as the ounce of surface soil? Why not? One of the most important substances which plants get from the soil, and *must* have in large quantities to make their best growth, is nitrogen. The largest part of this necessary food the plants get from the *humus*, the material that makes soils black and that fire will consume. This is why we have learned to think of the *black* soils as the most fertile.[1]

This second experiment is to show, then, that soils are

[1] Soils, pp. 71–74.
Physical Properties of Soils, pp. 1–51.

always *mixtures* of inorganic with organic matter; and that the greatest part, from 85% to 99%, of nearly all soils is mineral—composed of pieces of rock which we call *stones* or *gravel* or *sand* or *silt* or *clay* according to the size of the pieces or grains.

There is a kind of soil occurring in several places in Illinois called *peat*. This is found in beds where a dense growth of plants has sprung up and fallen down year after year for ages, as on the margins of lakes and along banks of streams. As the mass of roots and stems and leaves decayed, some sand was mingled with it by the action of the water; but the great bulk of this soil is organic matter.

## Exercise III

*How Soil Particles Look When Magnified.*—Sprinkle a few grains of dry soil on a glass slide or a sheet of white paper and examine with a microscope or magnifying glass. Make drawings of several of the particles. Is their color white, gray, brown, red, or black? In shape are they round or irregular, smooth or angular? Are the particles single grains or several grains fastened together like crumbs?[1]

The ordinary classification of soils, as gravel, sand, silt, clay, and loam is based mainly on the size of the particles composing them:[2]

*Gravel*—a soil composed largely of pieces of rock whose diameters lie between 3 inches and $\frac{1}{25}$ of an inch.

*Sand*—a soil whose particles range from $\frac{1}{25}$ of an inch to $\frac{1}{500}$ of an inch in diameter.

*Silt*—a much finer soil in which the particles have diameters lying between $\frac{1}{500}$ of an inch and $\frac{1}{50,000}$ of an inch.

*Clay*—a soil in which the diameters of the particles range from $\frac{1}{50,000}$ of an inch to only $\frac{1}{250,000}$ of an inch.

*Loam*—a name given to a soil which is a mixture of two or more classes of soils. Most surface soils are loams, and are

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[1] Practical Agriculture, p. 40.

[2] The First Book of Farming, pp. 26–30.
Soils, pp. 51–53.

subclassified as *sandy loams, clay loams, brown silt loams*, etc., according to the class of soil that predominates in the mixture.

## Exercise IV

*Helps in Classifying Soils.*—Place a spoonful of each sample of soil on a board and moisten it with water. With the fingers mold each sample into a ball. Notice that the sand and sandy loams are crumbly, but that the clay and finest silts are plastic and sticky.

In a pint glass fruit jar place two or three large spoonfuls of soil and fill the jar half full of water. Shake thoroughly, then let the soil particles settle to the bottom of the jar. The heaviest particles sink most quickly, first the gravel, then the coarse sand, fine sand, silt, and clay in the order named. The finest silts and clays will remain for days suspended in the water. The relative thickness of the layers of the different sized grains in the bottom of the jar will help to classify the soils by showing the proportion of each in the mixture.

From the tests and examinations of the soils in Exercises II and III, try to classify each sample as gravel, sand, silt, clay, or peat, or as a gravelly loam, sandy loam, silt loam, clay loam, or peaty loam.[1]

## Exercise V

*A Study of the Weight of Soils.*—Take any small box and accurately measure its cubical content. Be sure that the samples of soil used are thoroughly dry. Fill the box and calculate successively the weights of a cu. ft. of sand, clay, loam, and peat. An acre-foot of soil = 43,560 cu. ft. What is the weight of an acre-foot of each of the types of soil that you have examined?[2]

Farmers speak of clay as a "heavy soil," and of sandy soils as "light." You will see that this cannot be because of their relative weights. The expressions in this case refer to the

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[1] Soils, pp. 53–60.

[2] Soils, p. 26.
Physical Properties of Soil, pp. 41–49.

comparative ease with which they can be cultivated. Clay soils when moist are sticky and clinging, hard to till, while sandy soils crumble readily and are much easier to work.

## Exercise VI

*How a Part of the Water Is Held by the Soil.*—If a marble or a pebble be dropped into a dish of water it comes out *wet.* That is, a very thin film of water adheres to the solid body and completely surrounds it. In Exercise III the microscope showed us that the soil is made up of little particles of matter more or less round in form. Since they are of this shape they cannot be packed perfectly tight and close; there will be little spaces, or pores, all through the mass composed of these spherical grains. This is a very important fact in its bearing upon farming, and we shall have more to say about it in other lessons. The water that falls upon the ground as rain and snow flows down through these pores, and a part of it clings to the surface of each little particle of soil. This water is called *film water*[1] and is of immense interest to the farmer because it is from this source that growing plants get their whole supply of water and all of the plant food which is taken from the soil. Now this fact should be clearly and firmly fixed in our minds: *The feeding ground of a crop is measured by the sum of the surfaces of the soil particles that make up that portion of the soil occupied by the roots of the crop.*[2]

It is in this respect that soils vary most. Suppose you have a box whose three dimensions are 12 inches each. How many croquet balls whose diameter is 6 inches can be packed in this box? You answer 8. Find the sum of the surfaces of these 8 spheres. You remember that the formula for the surface of a sphere is the square of the diameter multiplied by the factor $\pi$ (approximately $3\frac{1}{7}$). So we have: $6 \times 6 \times \pi \times 8 = 288\,\pi$, as the total surface area of the 8 balls.

Suppose that the balls have a diameter of only 3 inches. If these are arranged in the same box in regular layers there will

[1] The First Book of Farming, pp. 50–52.

[2] Soils, pp. 29–31.

be 4 layers of 16 balls each or 64 balls in the box. Computing the total surface of these 64 spheres as follows: $3 \times 3 \times \pi \times 64 = 576\ \pi$, we see that the sum of the surfaces of all the spheres in the box has been doubled while the volume remains the same. Each time that the diameters of the spheres filling a given space are divided by 2, the total surface is multiplied by 2.

Although the particles in any type of soil are not perfect spheres nor all of the same size, this principle holds true always, that as you reduce the size of the soil grains you increase in the same ratio the total interior surface of the soil.[1]

King in his book, *The Soil*, estimates that *the total surface of the soil grains in one cubic foot of sandy soil is about one acre, while in a clay soil it is nearly four acres.*[2] Since, in a moist but well drained soil all the water is held in the form of a film adhering to the surfaces of the grains, and this water holds in its solution the various substances that the roots of the plants need for food, thorough cultivation which pulverizes and fines the soil increases its water-holding, and therefore its feeding, powers.[3]

### Exercise VII

*To Determine the Differences in the Water-holding Powers of Different Soils.*—Get 5 small tin cans, make several fine holes in the bottom of each, and fit circular pieces of cheese-cloth in the bottoms of these cans to prevent any fine soil from sifting through. Then find the exact weight of each can and weigh out carefully just the same number of ounces of material for each, putting gravel into I, coarse sand into II, fine sand into III, clay into IV, and loam into V. Weigh again to be sure that you have the correct weights. Now set the cans in a shallow dish and fill them with water until the soils are saturated,—that is until all of the pores of the soils are filled. Next stand the cans where all of the *free* water—all of the water that is not retained as a film about the grains

[1] Physical Properties of Soil, pp. 1–8.
[2] The Soil, pp. 72, 73.
[3] Soils, pp. 80, 81.

of soil—can drain away by force of gravity. When drainage ceases, weigh each can again. The excess in weight over that of the can filled with dry soil indicates the amount of water absorbed by the soil.

Which soil absorbed the most water? Which soil has the least power to hold water? Do these results agree with previous statements about the amount of interior surface of soils as related to the fineness of the soil particles?[1]

## Exercise VIII

*Will Compact Soils Hold More Water than Loose Soils?*—Conduct this experiment exactly like the previous one, but pack the soils firmly in the cans before adding the water. If a farmer wants his soils to store up an abundant supply of moisture for his growing crops is it better to leave the surface of the soil loose or to roll it down as solid as possible?[2, 3]

## Exercise IX

*How Does Organic Matter in a Soil Affect Its Water-holding Powers?*—In this experiment get some dry, well-rotted manure and rub it between the hands until it is fine. Now mix with the gravel, sand and clay of the sorts used in Exercise VII, about one-tenth the bulk of this fine manure. Weigh the same amounts into the cans and add water. How does the amount of water retained by these soils compare with the results in Exercise VII?

Crops on sandy soils frequently suffer severely for want of water in times of drought. Would working more organic matter into the soil improve their power to resist droughts?[2, 4]

In speaking of the water in the soil three terms are used to describe the three forms in which it exists there:[1]

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[1] The First Book of Farming, pp. 40–42.
Principles of Agriculture, pp. 47–63.
Soils, pp. 80–83.

[2] The First Book of Farming, pp. 46–52.

[3] Physical Properties of Soil, p. 134.

[4] The Principles of Agriculture, p. 52.

The *free water—gravitation water*, as it is usually called—is that portion of the water falling upon the surface of the ground, that the soil particles are not able to take up and hold by the power of adhesion as a film, but which flows downward, by the force of gravity, through the open spaces between the soil particles, and is carried off in underground drains, or reaches the level where water stands in the soil.

The *film water*, which has already been described, is called also *capillary moisture* from the Latin word, *capilla*, meaning hair. Where the soil grains are very fine the spaces between them are correspondingly small; and as they connect with each other they form little hair-like passages, or tubes, through which this film water is able to rise, because, where these tubes are small enough, the attraction of their walls for the liquid is able to overcome the force of gravity that would force the liquid to flow down. In this way, as the water in the surface soil is taken up by the growing plants, or evaporated by the sun and winds, a new supply is being constantly pumped up from below to take its place, if the soil is kept in the right condition for these little tubes to do their work. This is one of the greatest problems that the farmer has to deal with. Unless an abundant supply of water is caught and held by the soil, and the system of little pumps kept in working order so that by capillary action they can raise this water where the roots can reach it, it is no more possible to grow large crops than it would be to grow good live stock on a farm where there is not a sufficient supply of drinking water.

The third form of soil water is called *thermal moisture* or *hygroscopic moisture* and refers to a small amount of water that adheres so closely to the soil grains that it can be separated from them only by the use of considerable heat.[1]

### Exercise X

*The Capillary Action of Different Soils.*—For this experiment get 6 student lamp chimneys. Find a small wooden box the width of whose top is about the length of the chimneys.

[1] The Soil, p. 252.

Turn the box on its side with the open end toward you. Bore 6 holes in a row through the upper side so that the chimneys will pass through as far as the shoulder. (If you can not easily bore the holes, knock one of the boards off the side of the box and stretch two wires tightly across the right distance apart for the chimneys to pass between and be suspended by the shoulders.)

Tie pieces of cheese cloth firmly over the smaller ends of the chimneys and fill them up to the shoulders each with a different kind of soil. Pour the soils in loosely and do not try to pack them. Now fix it so that the lower ends of the chimneys shall stand in about one inch of water. Notice how the water rises through the pores of the soils. In which soils is the capillary movement most active? Fill one chimney with lumpy soil. Can the water rise through such a soil? This shows one reason why it is important to prepare the ground carefully before planting the seeds. About 3 inches from the top of the soil in one chimney put in a teaspoonful of fine dry chaff and then fill up with soil. Can the water rise through this chaff?

Sometimes farmers plow under a heavy crop of clover or rye, or a very thick coat of unrotted, strawy manure, and if the season is dry the crop suffers for lack of water because the capillary movement of the water from below is stopped by the loose layer of vegetable matter before it can reach the roots of the plants.

This same experiment can be performed by using large plates or pie tins, piling the soils in the center of these in the form of cones. Pour the water slowly upon the dishes at the base of the pile and observe how it rises through the different soils.[1]

**Water.**—No problems in agriculture are of greater importance to the farmer than those that deal with water. How to provide for the storage in his soil of an ample sup-

[1] The First Book of Farming, pp. 49, 50.
The Principles of Agriculture, pp. 55–59.
Soils, pp. 87–96.

ply for the needs of his crops; how to get rid of an excess of water in his soil; how to cultivate the soil so that the water stored in the subsoil can rise by capillary movement when it is needed to supply the demands of the plant roots near the surface; how to prevent the great loss of water by evaporation from the surface of the soil; and how to prevent the water in hilly regions from washing and gullying out the soil on the hillsides and carrying off into the streams the most fertile portions of the land—these are all questions that make the study of the control of water on the farm of the greatest interest and value.

The amount of water that falls from the clouds as rain and snow is measured by inches. The average annual rainfall in Illinois is 37.39 inches.[1] This means that if none soaked into the ground or ran off, and none evaporated into the air for a year, and that if the ground were perfectly level, there would be all over the state of Illinois on every acre of land a pond more than $3\frac{1}{3}$ feet deep as the result of the rainfall and snowfall for one year.

We sometimes speak of an acre-inch of water. That means the amount of water that would cover an acre with water one inch deep. There are 43,560 sq. ft. in an acre. An acre-foot of water would be 43,560 cubic feet on an acre. A cubic foot of water weighs very nearly $62\frac{1}{2}$ lbs. Compute the number of tons of water that fall annually on an average on each acre in Illinois.

**The Demands That Crops Make Upon the Water Supply in the Soil.**—The amount of water that is found in the plant at any one time is a very small part of what the plant uses in growing. Far the largest part of the water that the roots of plants drink up from the soil serves simply as a *carrier* of plant food and flows up through the roots and stems, leav-

[1] University of Illinois Agricultural College Experiment Station Bulletin No. 86, pp. 61, 62.

ing its loads in the cells of the leaves, and passing out into the air.

The amount that is thus used by our farm crops sounds enormous. For instance, to grow *one pound* of dry vegetable substance it has been proved by experiments that the plant uses from *300 to 600 pounds* of water. The following statements are made by prominent scientists who have conducted tests to learn how much water different crops use while making their growth (the figures are given for the average-sized crops per acre): clover uses 400 tons of water per acre; potatoes, 400 tons; wheat, 350 tons; oats, 375 tons; corn, 300 tons.[1]

**Saving the Soil Water.**—Since these various crops use such enormous amounts of water during the time they are making their growth, and since, if this supply is not provided for them as they need it, the crop yields are seriously shortened, the farmer should be taught to regard the supply of moisture stored in his soil as a part of his capital and so valuable that he must try to prevent its being wasted.[2]

### Exercise XI

*How to Check Evaporation of Water From Soils.*—Fill four tin pails of about 5-lb. size with loam to within two inches of the top. Moisten the soil well, measuring out the same amount of water for each pail. Whenever more water is added during the experiment, treat all alike. Put the same amount of soil by weight into each of the four pails and press the surface down smoothly, about as it would be left by a field-roller. Set

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[1] Practical Agriculture, pp. 12–15.
Soils, pp. 76–79; 237–239; 264.
The First Book of Farming, p. 40.
The Soil, pp. 155, 156.

[2] The First Book of Farming, pp. 53–57.
The Soil, pp. 184–190.
Soils, pp. 90–92.
Farmers' Bulletin, No. 266.

the pails, numbered I, II, III, IV, where the sun will shine on them and the air circulate over them. The surface of the soil in No. I should be left smooth. Each morning with a lead pencil stir the surface of the soil in No. II thoroughly to the depth of *one* inch. Treat the soil in No. III the same as in No. II except to stir it to a depth of *two* inches. Sprinkle over the surface of No. IV an inch layer of dry sawdust or wheat bran. Set down in four columns under I, II, III, IV the weights of each pail and contents at the beginning of the experiment and then the successive weights taken each morning. Continue the experiment for ten days or two weeks. What was the total loss of weight from each pail? That is, how much water has evaporated from each? Does stirring the surface of the soil check the loss of water? Does cultivation to a depth of one inch prove as effective as to a depth of two inches? This loose layer of soil obtained by surface cultivation is called a *dust mulch* and is the simplest and most satisfactory means by which the farmer can check the great loss of water from the soil by evaporation. How did the mulch of sawdust or bran compare in effectiveness with the dust mulch? In gardens and orchards of young trees a mulch of strawy manure, leaves, or the clippings of the lawn can be used to help prevent the loss of moisture. The loose mulches check the rise of moisture to the surface from below by capillary movement because the particles do not lie in close contact with each other and the water cannot pass from one soil grain to the next.

Another way in which there is a great loss of water from the soil is through the weeds that are often allowed to cover the ground. Each weed is a pump drawing the precious water out of the soil and passing it up through the stem and leaves into the air. This is unquestionably the worst of the many injuries that weeds cause the crops.[1]

**The Effect of Color on the Temperature of Soils.**—An abundance of humus in the soil gives it a dark color. Usu-

[1] The First Book of Farming, p. 54.
Soils, pp. 158, 159.

ally for this reason the surface soil is darker than the subsoil. Peaty soils and the leaf mold in the forest are nearly black.[1]

### Exercise XII

*Dark Soils Are Warmer than Light Soils.*—Fill two or three boxes or basins with soils of different colors, having one as dark and one as light as you can find. Set them where the sun can shine on them for some time. Then take the temperature of each soil with a thermometer, placing the bulb about two inches below the surface.

If you cannot easily find soils that differ considerably in color, cover the surface of one of the soils with a thin layer of crayon dust or lime, and the surface of another soil can be made black by sprinkling some soot over it. How much difference do you find between the temperature of a dark soil and that of a light one when the sun has been shining upon them for five or six hours?[2]

### Exercise XIII

*A Wet Soil Is Colder than a Dry Soil.*—A wet soil is kept cooler than a dry one. The heat that is used in evaporating the water with which the ground is saturated is taken from the soil, thus lowering its temperature.

Fill three boxes respectively with *wet* sand, loam, and clay; and three other boxes with the same soils in a *dry* condition. Set them in the open air where evaporation will be rapid. Placing the bulb of the thermometer two inches below the surface, test the differences in temperature between the wet and dry soils. This is one reason why wet land does not produce as good crops as a well-drained soil.[3]

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[1] The Soil, p. 230.
Physical Properties of Soil, pp. 161, 162.
How Crops Feed, pp. 190–193.

[2] Physical Properties of Soil, pp. 174–177.
Soils, p. 33.

[3] The First Book of Farming, pp. 60, 61.
The Soil, pp. 225–228.

# PART II

## STUDIES IN GROWING CROPS

**The Plant.**—To most people farming is, first of all, the business of growing crops. *The skilful and successful farmer is the one who can grow large crops at a good profit and without lessening the power of the land to continue to produce equally good or better crops each succeeding year.*

The study of agriculture has for one of its objects to teach how to accomplish these results.[1]

**Essentials in Crop Production.**—There are certain things that are absolutely necessary to grow crops; namely, *the seed, the soil, moisture, heat, light,* and *plant food.* Let us consider each of these in turn: The life history of a plant forms a complete cycle. Starting at the place in its existence which we call the *seed* and passing through its different stages of development, it comes in time to the point where it in turn produces seeds like the one from which it started; and then, having completed the work for which it was created, it dies[2] and its parts are gradually broken up and decomposed and all of the materials which were used in its growth are finally given back to the air, the water, and the soil in the same forms and amounts as those in which they were taken. Nothing has been lost and nothing gained; there has occurred simply a marvelous series of changes caused by the mysterious forces of Nature which work always according to the same laws.

Some plants complete the whole cycle of their life history in one season and then die. Such plants are called *an-*

[1] The Principles of Agriculture, pp. 1, 2; 106–144.

[2] In the case of perennial plants the process of producing seeds may be repeated many times before the death of the plant occurs.

*nuals.* Those that need two seasons to accomplish their life work, and die the second year, are termed *biennials.* The third class is named *perennials* and comprises those plants that do not die after producing a single crop of seeds, but live on many years, some many centuries.

The plant during its life has two kinds of work to do that are spoken of as *nutrition* and *reproduction.* That is, the plant must first take care of itself—feed and grow; then it must produce other plants like itself. These offspring when first produced by the parent plant we call the *seed.*[1]

**The Seed.**—You must think of a seed as a *baby plant* tucked up in its lunch basket with its food closely packed all about it and a covering—sometimes two or three coverings—tightly stretched over baby and lunch for protection from wet and other injuries.

Here the little fellow lies just as his mother fixed him last summer, waiting to be set free. This process by which the plantlet emerges from the seed and establishes itself in the soil and the air is called *germination.*[2]

### Exercise XIV

*Essentials for Seed Germination.*—Select five flower pots or boxes holding about a quart of soil. Number them in a series (1), (2), (3), (4), (5), and fill nearly full with good garden soil that is thoroughly dry. In each pot plant two kernels of corn and two beans. (Any seeds may be used, but corn and beans are large and more easily studied.) Before planting the seeds in pot (1) put them in a cup and pour boiling water on them. Leave them in the hot water but a few seconds and

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[1] Farmers' Bulletin, No. 257.

[2] The First Book of Farming, pp. 70–80.
Farmers' Bulletin, No. 111.
Practical Agriculture, pp. 1–5.
Farmers' Bulletin, No. 229.

then plant them about two inches deep in the soil of pot (1). In the same way plant the same number and kinds of seeds in each of the other pots. Next moisten the soil in all of the pots except in (2), but leave that perfectly dry. Set No. (3) where the temperature is below 40° F. If the experiment is tried in the winter this pot may be kept in a cold room, but in the summer it will be necessary to set it in the ice-box at home. In the case of No. (4) put a cork in the bottom of the flower pot so that the water cannot drain out. Then pour on water until the soil in this pot is fully saturated and can hold no more.

In No. (5) the conditions are the same as those that we try to secure for the seeds that we plant in the garden and field; namely, the seeds that are planted have received no injury and so the little plants within the seeds possess strong vitality (the seeds in No. (1) were injured by extreme heat); the soil has sufficient moisture to soften the seed coat and cause it to swell and burst open so that the root and stem can escape and to dissolve the foods which the plant needs (the soil in No. (2) was left dry); the soil is warm from the sun's heat which it has absorbed, and this warmth is necessary to set in motion the activities of the little plant (in No. (3) the seed is kept where the temperature is too low for the germinating process to start); the soil is porous and full of interstices through which air can pass and reach the roots, for air is just as essential to their existence as it is to an animal's (in No. 4, since the soil was saturated with water, there was no space for the air to reach the little plant and it must smother).

This experiment should be continued for ten days and then the seeds dug up from each pot and their condition examined. This is an exercise that every pupil should conduct for himself, for his interest will be greater in the results of his own work and he will be more apt to think for himself.[1]

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[1] Practical Agriculture, pp. 1–5.
The First Book of Farming, pp. 70–79.
The Principles of Agriculture, pp. 124, 133, 134.
How Crops Grow, pp. 349–357.
Farmers' Bulletin, No. 253.

**The Testing of Seed.**—The *seed* is one of the essentials of crop production. *Vitality* is one of the conditions necessary for the germination of the seed. A great many things may happen to seed to affect its vitality, either to destroy it entirely or so to weaken it as to render it of no value in increasing the crop yield but only a detriment to the other plants among which it stands. The quality of the seed that is sown holds the same relation to the possible profits from the crop that the character of the cows on a dairy farm maintains to the profits of the dairy.

Every farmer should thoroughly test all of his seed for field and garden use before planting. Comparatively few farmers test any of the seed they sow. The reason is that they have not been trained to this practice.[1]

### Exercise XV

*How To Test Seed.*—Get two large plates, fill one of them even-full of sand in which the seeds are to be planted, and, after moistening the sand moderately, cover with the second plate and set where the temperature is from 70° to 80°. Do not make the sand too wet, as that will exclude the air. If this work is to be done in cold weather in buildings where heat is not kept up during the night, get a tight box of desired size, fit on a lid with leather hinges, and line all the sides of the box with several thicknesses of newspapers. To supply heat place an earthen-ware jug, holding one or two gallons, filled with hot water and tightly corked in the bottom of the box.

To test seed corn, number each ear to be tested with a piece of paper pinned to the butt. Make grooves in the sand on the plate and number these with bits of paper to correspond to the numbers of the ears. Select kernels from different points both lengthwise and around the ear; for one portion is sometimes injured while the other part is sound. Leave the kernels in the moist sand for five to eight days before examining them. The test should show not only whether the germ is alive, but

[1] The First Book of Farming, pp. 75–77.

whether it is vigorous. Sometimes a seed of weak vitality will send out a root but lacks strength to develop the stem of the young plant. It is not safe to use such ears for seed. Have the pupils make their own tests independently for the same ears and compare results.

Also test in the same way other seeds—clover, grasses, wheat, oats, and garden seeds—planting 25, 50, or 100 seeds of each kind and recording the percentages of germination. Exercises in testing seeds may be conducted with profit throughout the whole year in order to fix the habit and impress the importance of doing this work on the farm.[1]

**Importance of Fine Tilth.**—The conditions of moisture, temperature, air, and light which the baby plant meets in its immediate environment when it first emerges from the seed determine its chances of success. If it gets a "set-back" at the start it rarely recovers vigor.[2]

### Exercise XVI

*Why a Good Seed-bed is Necessary.*—Fill one of two boxes or flower pots with fine, mellow loam and the other with coarse soil in which the lumps are as large as peas or larger. Plant two or three grains of corn and of wheat or oats or radish seed in each. Give to each pot the same amount of water and observe whether the seeds in each pot germinate at the same time and grow with the same vigor.

In the coarse soil the spaces between the soil particles are so open that the film-water cannot pass freely upward by capillary movement and the tiny rootlets are liable to die or seriously suffer for lack of moisture.

The soil in which seeds are sown should be fine and pressed down so that it is in close contact with the seeds.

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[1] University of Illinois Agricultural Experiment Station Bulletin, No. 96.

Farmers' Bulletin, No. 253.

[2] The Soil, pp. 277–279.

Soils, pp. 98–100.

## Exercise XVII

*Heavy Soils Should Not Be Cultivated When Wet.*—Soils whose particles are very fine, such as clay and silt, are sticky and difficult to handle when wet, and lose their granular texture if cultivated at this time. These soils are called *heavy* in contrast with the light sandy soils in which the grains never stick tightly together even when wet.

Fill two pots with dry, fine clay soil and one with sandy soil. Add water enough to make one of the pots of clay and the pot of sand quite wet, and then thoroughly stir the wet earth with a stick until it becomes pasty. Plant seeds in each of the three pots, moistening the second pot of clay after planting the seeds, but not stirring the earth while it is wet. Set the pots where the sun can shine on them. Notice that a hard crust forms over the clay soil which was handled when wet and may exclude the air so completely that the seeds under it cannot germinate, and it will be very difficult, or impossible, for the young stems to force their way up through it. This will not be the case with the wet sand nor with the clay that was handled while dry.[1]

## Exercise XVIII

*The Color of the Soil Influences Plant Growth.*—This experiment should be conducted about October 1st, or May 1st, when the nights are cool and the soil is not thoroughly warmed through.

Get a box 4 to 6 feet long and 2 feet wide; set it on benches where the sun can shine on it all day and fill it to a depth of 10 to 12 inches with good surface soil. Draw a line lengthwise through the center of the box; also draw cross lines dividing each half of the box into plots of one square foot. If the box is 6 feet long, there will be 6 plots above the dividing line and 6 plots below it. Number these plots from 1 to 6 on each side of the line. In each of the two plots numbered (1), plant

[1] The First Book of Farming, p. 45.
Soils, pp. 57, 58.
Farmers' Bulletin, No. 77.

10 grains of corn; in plots (2), 10 beans; in plots (3), 10 kernels of wheat; in plots (4), 10 grains of oats; in plots (5), 10 peas; in plots (6), 10 radish seeds.

If the color of the soil is naturally dark, cover the 6 squares on one side of the line with a thin coat of white sand, or of lime; but if the soil is a light color, darken one side of the box with a thin covering of soot. See that the soil is properly moist.

At the same time each day record the number of plants of the same sort that show above the surface. For example:

| Oct. 5, | | | Oct. 6, | |
|---|---|---|---|---|
| Corn | dark—3<br>light—0 | Beans | dark—5<br>light—2 | Corn | dark—6<br>light—2. |

This exercise will demonstrate two facts; namely, dark soils absorb more heat from the sun than light soils; seeds germinate in less time, and plants grow more rapidly, in a warm soil than in a cool one.[1]

The color of the soil is, to a considerable degree, within the control of the farmer, since increasing the organic matter in the soil (as by use of farm manure) makes the color darker.[1]

**Seed Planting.**—This is a subject about which it is easy to get exact information for one's self through experiments with the seeds and the soil. Why do seeds need to be buried in the soil in order to germinate and grow? Has the action of light on the roots of the young plant any effect, and if it has, is it helpful or harmful? How deep ought seeds to be planted? Do some seeds endure deeper planting than others? Does the depth of planting affect the later growth of the plant?[2]

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[1] The Principles of Agriculture, pp. 119, 120.
The First Book of Farming, pp. 73, 74, 81–83.
Soils, pp. 35, 36.
How Crops Feed, pp. 190, 191.

[2] How Crops Grow, pp. 355–357.
The Principles of Agriculture, pp. 135, 136.

## Exercise XIX

*How Deep Should Seeds Be Planted? What Is the Effect of Light on Germination?*—Make a box that shall have one side enclosed by a pane of window glass. The box should allow from 10 to 12 inches depth of soil, a width of 6 inches and a length of 12 to 20 inches. Prepare some fine, mellow garden soil and place 2 inches of it in the bottom of the box. At the right-hand end of the box lay one kernel of corn on the soil close against the glass and another kernel near the back of the box away from the light. At the left-hand end plant in the same way 2 beans. Then cover with 1 inch of soil and plant 2 more seeds of each kind in the same way as before, only placing them a little nearer the middle of the box so that they shall not be directly over those planted below. Continue with successive layers of soil 1 inch in thickness until near the top of the glass, then cover the last planting of seeds with but ½ inch of soil. Place 2 other seeds of each kind on the surface with no covering at all of soil.

Set the box in a sunny window and supply the necessary water to keep the soil moist. Make records of the time when each plant appeared above the surface, and compare from week to week the height and vigor of the different plants. What depth of planting gave the best results in growth with corn? Was the same depth the best for beans, also? Does it seem more difficult and require more energy for the bean plant to get its stem up through the soil than is the case with the corn plant? Why is this?

Does there seem to be any difference in the rate of growth between the plants from seeds exposed to the light and from seeds placed in the back of the box? If there are differences, can you give any theory to explain them? What has happened to the seeds lying on top of the soil?

If this experiment is attempted in school, let each member of the class have his own box and perform the work independently; and when the records are all finished compare them and see what they teach.[1]

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[1] How Crops Grow, pp. 353–357.

## Exercise XX

*The Young Plant Depends on the Food Stored in the Seed.*—In moist sand between two plates germinate 10 kernels of corn. When the roots are about 2 inches long carefully remove with scissors the kernels from 5 of the plants and then transplant the whole 10 plants into a box of moist soil or sand. Notice the difference between the rates of growth of the 5 plants having the grains attached to their roots and the 5 other plants from which the grains have been removed. Can you see why plants grown from large, plump seeds should be more vigorous than those from small and shrunken seeds?[1]

## Exercise XXI

*The Young Bean Plant Brings Its Supply of Food above Ground with Its Stem.*—In a pot of moist sand plant 4 beans. Notice how the stems get up through the soil, bending to form a loop and *pulling*, instead of *pushing*, their seed-leaves up into the air. Now carefully with the scissors, so as not to injure the other parts of the plant, remove the seed-leaves from 2 of the 4 plants. For the next two or three weeks compare the growth of these 2 plants with the others. The results are like those of the corn plant.[2]

## Exercise XXII

*Light Is an Essential of Plant Growth.*—Prepare 4 boxes or pots of garden soil and plant a half dozen grains of corn and beans in each. After the shoots appear above the surface, place one pot where it will be in direct sunlight, and a second in the center of a light room, but where the sun cannot reach it; set a third pot in the dimmest corner of the room, and put the fourth pot in a dark closet. Try to have the conditions of temperature and moisture the same for all of the pots. At the

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[1] The First Book of Farming, pp. 77–80.

[2] How Crops Grow, pp. 350, 351.

end of 10 days place them together on a table, compare them and record their differences. Then exchange the places of No. (1) and No. (4), and of No. (2) and No. (3). At the end of a week compare again and notice results. Now set them all together in the sunshine for a few days and notice if they assume the same appearance.[1]

## Exercise XXIII

*To Show How Rapidly Plants Transpire Water.*—Get a wide-mouthed pint bottle, a thick cork that fits the bottle, and a vigorous, straight-stemmed plant 10 or 12 inches high. A thrifty tomato plant or a ragweed does very well for this experiment. Remove the plant from the soil carefully so that the roots shall be injured as slightly as possible and gently wash off all soil particles. Place the roots and lower part of the stem in the bottle and fill with water up to the neck of the bottle. Cut the cork into two equal pieces and in each half hollow out with a knife grooves so that when the cork is inserted in the neck of the bottle the two pieces will fit snugly about the stem of the plant. Now spread a few shavings of paraffine on the cork, warm the blade of a knife and with it melt and spread the wax over the top of the cork and around the stem of the plant so that no water can escape when the bottle is inverted. It is now certain that all water that gets out of this bottle must pass up through the roots, stem, and leaves of the plant. Set the bottle and plant in a window where the sun can shine on it all day long and notice how fast the water is taken out. If a single root reaches to the bottom of the bottle, every drop of water will disappear.

If several pupils are trying this experiment, notice that the plants having the greatest leaf surface take up the water most rapidly. As the water becomes exhausted, watch the changes taking place in the plant.[2]

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[1] The First Book of Farming, pp. 108–115.

[2] The Principles of Agriculture, pp. 114, 120, 125.
How Crops Feed, pp. 202 and 208.

## Exercise XXIV

*Weeds May Rob the Soil of Moisture.*—Get 2 small tin pails, such as were used in Exercise IX, and fill each with good garden soil. Into one of them carefully transplant a young, lusty-growing plant (something like ragweed answers the purpose well, but the size of the plant selected, especially the development of its roots, should be suited to the capacity of the pail used).

Now make the weights of the 2 pails and their contents exactly the same by removing, if necessary, a little soil from one of them. Place both pails in a warm, sunny spot and give the soils in each exactly the same treatment; that is, keep the surface of the soil in each pail cultivated in the same way, and whenever water is added to the growing plant in the one pail, pour exactly the same amount upon the soil in the other pail. At the end of one or two weeks take the weights again. The difference in weights will show how much more water has been lost into the air from the soil in one pail than from that in the other because of the plant growing in it.

This is a practical question for farmers to consider in the preparation of their corn ground in the spring. If the plowing of the field is left until just before planting and the clover or grass is allowed to grow, so much moisture may be taken out of the soil that the corn crop will suffer for lack of water.[1]

## Exercise XXV

*What Proportion of a Green Plant Is Water?*—With a sickle cut off close to the roots a few bunches of clover or of oats, a green potato top, a tomato plant, or handfuls of any green weeds. Tie up each bunch carefully by itself and take the weights accurately of all of them. Then hang them up where they will become thoroughly air-dried and once more take their weights. The differences between the first and second weights show how much water, in the form of *sap* or *juice*,

[1] The First Book of Farming, p. 54.
Soils, pp. 158, 159.

was in each bunch of green plants. In each case divide the weight of water that has been evaporated from the bundle by the weight of the dried plants and express the quotient in percentages of the air-dried material.

**Roots.**—One of the three main divisions of a plant is the root. Roots perform three principal offices for the plant; namely, (1) they anchor it securely in the soil where it is to grow; (2) they gather and absorb the water and plant foods from the soil; (3) in many cases they serve as the storehouses where the plant lays up its reserve stock of foods for future use.[1]

The usual home of the roots is in the soil; but sometimes, as in the case of the brace-roots of a corn plant, or the organs by which the ivy clings to a wall, roots grow in the air. On the other hand, not all the parts of a plant that grow underground are roots. Some plants have underground stems, so commonly seen in certain grasses; and the tubers of our ordinary potato plant are not parts of the root of the plant, but of the stem, the *eyes* being merely *buds* on these stems.

There are two different kinds of root systems among plants known as the *tap-root* system and the *crown-root* or *fibrous-root* system. The carrot represents an extreme type of the first sort, and a strawberry, plantain, and all the grasses and cereals belong to the fibrous-rooted class of plants.

In collecting plants for class study, remove them from the soil with as much of the root system attached as possible, and by supporting the plant with its roots suspended in a glass vessel of water, the roots will show their natural position in the soil, and very correct mental pictures of how

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[1] The First Book of Farming, pp. 9–22.
The Principles of Agriculture, pp. 113, 124, 130, 131.
How Crops Grow, pp. 256–282.

they spread through the ground may be obtained and drawings made.

Sow seeds of different kinds of plants in boxes of light, sandy soil, so that the plants can be taken up easily without breaking the roots, and examine and sketch the different root formations at various stages in the plant's growth.[1]

## Exercise XXVI

*How Roots Search for Water.*—Fill 2 flower pots with sand and plant in each 2 kernels of corn and 2 beans. Set one of the pots in a shallow dish in which about an inch of water is allowed to stand. At first moisten the surface of the sand enough, so that the seeds will germinate, and then give the plants no more water from above, but let them seek it in the bottom of the pot. On top of the sand in the second pot lay a handful of fine moss, or two or three thicknesses of cloth, and keep this constantly moist, but never put on water enough to moisten the soil more than 2 inches deep. After the plants have grown in these pots 3 or 4 weeks, carefully invert and jar the pots so that the contents will slip out, then wash the sand away from the roots and compare their positions and development in the two pots.

Does this show you why it is a mistake during a hot, dry spell to give frequent light sprinklings of water to the lawn and garden rather than occasional heavy drenchings in which the water will saturate the soil to a depth of several inches?

Will not the first method induce the roots to grow close to the surface where a single hot day may seriously injure them?[2]

## Exercise XXVII

*How Do Roots Know Where to Look for Food?*—During the period of germination, while the plants are living on the

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[1] The First Book of Farming, p. 65.
The Principles of Agriculture, pp. 113, 114.
How Crops Grow, pp. 39, 40.

[2] How Crops Grow, pp. 276, 277.

food stored in the seeds, the roots develop equally well in a sterile sand or a fertile loam; but after the food supply in the seeds is exhausted, the roots in the poor soil grow long and slim and have a "hungry look," while those in the rich soil grow short and thick.

In this experiment you may use several cubical boxes of 1 foot dimensions. Fill part of the boxes with sand that has little or no plant food in it, and the others with as poor clay soil as you can find, where plants grow poorly. In one box, place a handful of rich well-rotted manure in the bottom and close to one side; in another box, spread a layer of such manure over the whole bottom of the box; in a third, place the manure in a compact mass in the center of the box directly under the plants; in the fourth, mix the manure evenly through the whole soil; and in the last one, do not use any fertilizer. In the center of each box plant 2 or 3 seeds of corn and beans and set the boxes in a light warm place. Water them properly, and at the end of 3 or 4 weeks knock off the sides of the boxes, carefully wash away the soil from the roots, and notice what has been the character of their growth in each case.

Such exercises furnish excellent material for work in drawing, and training in keeping note books.

The results of this exercise should teach the importance of mixing the fertilizers in the soil as evenly as possible, as well as the value of supplying plant food to the crops.[1]

## Exercise XXVIII

*How Plants Use the Reserve Food Stored in Their Roots.*— Notice how in the early stages of growth the roots rapidly increase in size and are juicy and brittle. The starch food (carbohydrate) made each day in the leaves of the plant from the raw (inorganic) materials taken from the air and the soil, is being packed away in the root for future needs. As the season advances, look for a radish plant that has begun to send out from the top of its stem a flower-stalk. Now another kind of work is being done by the plant. The process called *reproduc-*

[1] How Crops Grow, p. 263.

*tion* is in operation. This new work makes a heavy demand upon the energy and food of the plant, and the amount which the leaves can make each day is not sufficient to meet this demand. But the provident little radish plant has a plump bank account and begins to draw upon it. Pull up the plant and cut across the root. It is *spongy* and *stringy.* Much of the starch that made it so brittle at first has been removed in building the flower and seeds, and the *strings* are the cellulose fibers that served as the framework and partitions of the storehouse in which the food was packed.

Plant the roots of beets, carrots, and turnips in the spring and notice that this same thing happens to them as they form the seed. In the case of wheat, oats, corn, and the other cereal grains, this extra food needed to help make the flowers and seeds is stored for the most part in the stems or stalks, and as the processes of seed-building go on, these stems lose their juices and become more hollow and brittle and yellow and finally give up their lives altogether, or transfer them, to the baby plants that now lie tucked away so snugly in the dry, hard seeds.

**Root Tubercles.**—Of all the remarkable things that science has done for agriculture, perhaps none has attracted so much notice or promises to play so important a part in the business of farming as the discovery that by growing certain kinds of crops, called *legumes,* nitrogen can be obtained from the atmosphere and fixed in the soil in a form that is available as plant food. So important is the knowledge which this discovery has given to the farmers that its general acceptance and use will mark the beginning of a new agriculture.

Nitrogen is one of the ten elements absolutely essential to the growth of every plant. Of all the substances except water taken from the soil by the plant through its roots nitrogen is used in much the greatest amounts. To grow 100 bushels of corn, 148 pounds of nitrogen are removed from the soil; a 40-bushel crop of wheat takes away 65 pounds of nitrogen; a 75-bushel crop of oats, 69 pounds of nitrogen;

3 tons of clover hay, 120 pounds of nitrogen; 8 tons of alfalfa, 400 pounds of nitrogen; 300 bushels of potatoes, 63 pounds of nitrogen.

The supply of nitrogen in most soils is not so great but that a few years of heavy cropping under the systems of farming that have been in common practice will so reduce the stock of this essential plant food that large yields from the land are impossible. Wide areas of our country reached this condition years ago.

Many farmers have tried to keep up the supply of nitrogen in the soil necessary to meet the needs of large crops by the use of commercial fertilizers containing this element, but their cost in the market is so great that it is doubtful whether there is any profit in using them on ordinary farm crops. In the forms in which nitrogen is generally sold for fertilizing purposes, it costs the farmer about 15 cents a pound. At this price the farmer who raises 100 bushels of corn and sells it, both grain and stalks, is shipping off from his farm in this one crop $22.20 worth of fertility in the form of nitrogen alone, to say nothing of the other plant foods, phosphorus and potassium, which must be accounted for. That is, if he returns to the land, by purchasing commercial nitrates, as much nitrogen as he has taken out of it in this single crop, it will cost him this amount; and if he does not return it in some way, the land is rapidly losing its power to produce good crops.

In the atmosphere everywhere about us and circulating through the open spaces in the soil is a measureless supply of this valuable plant food in the form of a gas; for about four-fifths of the air by weight is nitrogen. However, the plant unaided cannot use this material and will starve for want of it while surrounded by it. But it has been discovered that a certain class of plants, called legumes (plants that produce their seeds in pods, like the beans, peas, clovers, etc.), have a means, which other classes of plants have not, of getting ni-

trogen from the air. Every pound of nitrogen thus secured is, of course, clear gain; for it does not cost the farmer a cent, nor is he taking it from his neighbor. Every boy and girl before leaving school ought to know about this provision of Nature, which makes it possible for the farmer *to use and still have*, if he understands how to accept the gifts that are offered him.

The legumes most commonly grown as farm crops in Illinois are the clovers, alfalfa, soybeans, cowpeas, Canada field peas, and vetch.[1]

## Exercise XXIX

*How Leguminous Crops Increase Soil Nitrogen.*—Find some place where clover, cowpeas, or soybeans grow vigorously and with a spade lift a few plants out of the soil. Examine the roots to find attached along their sides little tubercles, or nodules. These will vary in size from that of a pin-head, on the clovers, to a large pea, on the soybeans and cowpeas. These little masses of matter are homes where colonies of microscopic organisms, so small that it is said 10,000 of them placed side by side would not measure more than an inch, have located themselves. The plant on whose roots they grow is called the *host.* The bacteria that make their homes on the roots of the red clover, for instance, are not like those that live on the cowpeas, and these in turn differ from the bacteria that are found on the soybean. As far as is known there are only two legumes that serve as hosts for the same kind of organisms, and they are alfalfa and sweet clover.

The relation established between each kind of bacteria and the sort of plants congenial to it is one of mutual benefit. Such a relationship is called symbiosis. In this case the bacteria draw their nourishment from the juices of the roots of

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[1] The First Book of Farming, pp. 68, 144–146.
Soils, pp. 329, 330; 333, 334.
The Soil, pp. 124, 125.
University of Illinois Agricultural Experiment Station Bulletin, No. 94.

the plant, and in return they give to the plant a food rich in nitrogen, which they have made out of the free nitrogen in the air. So if these leguminous crops, which have built into their tissues the nitrogen taken from the atmosphere, are plowed under as green manure, or are fed to stock on the place, and the manure thus made is returned to the field, a considerable addition can be made to the stock of nitrogen in the soil.

These bacteria live in the soils where plants congenial to them grow. They will not thrive and multiply in a soil that is not in a good physical condition—that is wet, cold, not well ventilated, or acid. Therefore if we want these remarkable creatures to work for us we must find what their tastes are and then provide the conditions that suit them. If you examine some legumes and fail to find any nodules on their roots it is probably because the soil conditions are not favorable to them and ought to be improved, or because their particular host plant has not been growing in that soil for several years, at least. In such case it is necessary to introduce these bacteria by placing a few of them in the soil.

Make a collection of as many kinds of leguminous plants as you can find with these tubercles growing on their roots. Good specimens of some of these plants should be preserved in glass fruit jars in a solution of formalin.

In Bulletin No. 94, issued by the Agricultural Experiment Station of the University of Illinois, Dr. Cyril G. Hopkins says: "In general the clover bacteria are well distributed over the northern and central part of Illinois, but we now have some very strong evidence that they are not well distributed in some soils of wide area in Southern Illinois. There is also some evidence that they were not originally present even in the soils where they are now found in great abundance; and, furthermore, it seems very probable that these bacteria may cease to live in a soil where they have once been present, provided clover is not grown on the land for several years.

"When clover is cut for seed, it is frequently left to lie upon the ground until the straw becomes half rotten and very dirty; and, consequently, when it is threshed, it practically always happens that there is at least some small amount of dust

and dirt taken with the seed. This dirt is almost sure to carry with it some bacteria from the soil. If these few bacteria are scattered with the clover seed when it is sowed they will inoculate at least a few plants, and if they are allowed to multiply on these plants, and especially if the same field is repeatedly seeded with clover, the soil will ultimately become thoroughly infected with the clover bacteria. Of course they may be carried from one part of the farm to another, or even from one farm to another, by various agencies, as dust or wind storms, surface drainage or flood waters, manure from clover hay, implements used in cultivating the soil," etc., etc.

## Exercise XXX

*Inoculating the Soil with Bacteria.*—Experiments to demonstrate how bacteria may be introduced into soils, and what the power of these organisms is to secure nitrogen for the legumes which serve as hosts, may be tried by growing the plants in pots or on small plots outside.

Get 3 flower pots or boxes that will hold about 4 quarts and fill them with soil. If this soil is heated 2 or 3 hours in a hot oven before putting it into the pots, it will ensure that no living bacteria are present in the soil except those that we put there.

Number the pots I, II, III, and plant in each a half dozen seeds of red clover or soybeans. Dissolve a tablespoonful of saltpeter (potassium nitrate) in a gallon of water and twice a week moisten the soil of pot I with this. In pots II and III add no plant food to the water used after planting. However, before the seeds for pot III are planted, get about a pound of soil from a field where the legume with which you are experimenting is growing and where plenty of tubercles can be found on their roots. Put this soil into a fruit jar containing a quart of pure water, shake it well for a few minutes, and then let it settle. When the seeds are placed in pot III pour a little of this clear liquid over each seed.

Now the differences in the conditions of these 3 pots are these: No. I has no nitrogen-gathering bacteria, but an abun-

dance of nitrogen for plant growth; No. II has neither the bacteria nor the nitrogen; No. III has no fertilizer supplying nitrogen, as No. I has, but the soil has been inoculated with the organisms that can get it for the plants from the air.

At first the growth in No. I will probably be much stronger than in II and III because in I the nitrogen is ready for the plants to use from the start; but after four or five weeks No. III will possibly outstrip I, and will far surpass II.

The soil that is used should be one that is quite deficient in nitrogen, or no marked results will be obtained; for if the soil is well supplied with nitrogen, few, if any, tubercles are formed even though there are bacteria in the soil. To get satisfactory results, this experiment should be continued for several weeks, and care must be taken to keep the plants from freezing. In any school where real interest in agriculture has been aroused some plan can be devised for getting around the difficulties. Suppose one pupil in the class is so much interested in trying this experiment that he offers to take the pots to his home, after they have been prepared and planted, and keep them in the window of a warm room until the plants are large enough to show results; then they can be taken back to the school and examined by the class. Remove the roots from the soil and examine them for tubercles.

If the school is in a town there will doubtless be some greenhouse where it will be possible to get permission to leave them for a few weeks; and it would not be a difficult matter to build in the fall on the south side of the schoolhouse or some near building a small hot-bed which can be covered with an old window, and on cold nights still further protected with a blanket or piece of carpet, and such a place may be made to answer admirably for growing and keeping plants that are needed for these exercises.[1]

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[1] Soils, pp. 333–337.

Farmers' Bulletin, No. 240.

University of Illinois Agricultural Experiment Station Circular, No. 70.

**Inoculating the Soil for Alfalfa.**—The tests that have been made with alfalfa in different parts of the state warrant the belief that this will become one of our most valuable crops when more is known about how to grow it. Let each school that teaches agriculture prepare two or three small plots for experiments in alfalfa. The plots need not be more than one square rod in area and all the work in the preparation of the seed-bed, inoculating the soil and sowing the seed can be done by pupils. For information about inoculating the soil for growing alfalfa consult Bulletin 94, previously referred to, where Dr. Hopkins describes the procedure in a series of pot experiments, and shows the results very effectively by photographs taken at different stages of growth. In all of the pictures the alfalfa plants growing in the pot of sand not inoculated with bacteria are feeble and stunted, making scarcely any growth after the first two or three weeks, while the plants in the other pots are growing luxuriantly and at the end of eight weeks appear to be more than ten times as large. Dr. Hopkins's conclusions should be carefully noted, containing, as they do, many practical suggestions for the farmer.[1]

**Plot Experiments.**—Pot experiments can be used during those months when outside work is impossible, and where it is desired to keep certain conditions under absolute control. The advantages in the plot tests are that the work is more like real farming and is carried on mainly under the same conditions. Moreover, if permanent plots can be established on or near the school ground, many of the experiments may be continued through a period of years, and the results obtained will grow in value as the time which they cover lengthens.

The circular prepared by Dr. Hopkins and printed by

[1] Soils, pp. 340, 341.

University of Illinois Agricultural Experiment Station Circulars, Nos. 110 and 70; Bulletin, No. 76.

Farmers' Bulletin, Nos. 215 and 240.

the University of Illinois, in 1904 (from which we quote in the following pages), gives directions for laying out plots and for securing and applying fertilizers for experimental work in soil fertility.[1]

**Purpose of the Experiments in Soil Fertility.**—The three food elements which must be kept in available supplies for the plant, are nitrogen, phosphorus, and potassium.

"To find what elements of plant food are most deficient in the soil we should experiment and see what effect is produced on the growth of plants by adding different plant food elements to the soil." [2]

**How the Necessary Fertilizers Can Be Obtained.**—"For nitrogen, dried blood should be applied. This contains from 12 to 14 percent of nitrogen in a form which is not likely to injure the plant even if used in some excess. A 100-pound bag of ground dried blood can be obtained from Swift & Company, Union Stock Yards, Chicago, for about $2.50.

"For phosphorus, steamed bone meal should be applied. The best steamed bone meal contains from 12 to 14 percent of the element phosphorus in a very good form for plants. A 100-pound bag of extra fine ground steamed bone meal ('Big Six' brand) can be obtained from Morris & Company, Union Stock Yards, Chicago, for about $1.25.

"For potassium, use potassium chlorid. This is a salt which usually contains from 40 to 42 percent of the element potassium. A 100-pound bag of potassium chloride can be obtained from Armour Fertilizer Works, Union Stock Yards, Chicago, for about $2.50.

"Armour Fertilizer Works, Union Stock Yards, Chicago,

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[1] University of Illinois Agricultural Experiment Station Bulletin, No. 94.

[2] University of Illinois Agricultural Experiment Station Bulletins, Nos. 99, 115, and 123.

University of Illinois Agricultural Experiment Station Circulars, Nos. 72, 96, 100, and 108.

have agreed to furnish a one-pound package of potassium chloride, a two-pound package of fine ground steamed bone meal, and a four-pound package of ground dried blood for a total charge of seventy-five cents, the purchaser to pay express charges.

"These quantities are ample for pot culture experiments."

## Exercise XXXI

*A Test in Plant Food Requirements.*—"For plot experiments, a series of ten plots should be laid out with division strips (sunken paths) between them at least two feet wide. (Care must be taken not to mix the soil from adjoining plots by cultivating, especially if the experiments are to be continued for several years.) Each plot should be at least ½ rod wide and 2 rods long, which would make one square rod or 160th part of an acre."

Where, for any reason, plots cannot be used the same experiments may be carried on in earthen-ware pots.

"A very complete experiment can be made with 10 pots, or with 10 plots, arranged as follows with the applications of plant food indicated:

*How Plant Food Is Applied.*—

| | | | |
|---|---|---|---|
| 1 | None (Check). | 6 | Nitrogen, phosphorus. |
| 2 | Nitrogen. | 7 | Nitrogen, potassium. |
| 3 | Phosphorus. | 8 | Phosphorus, potassium. |
| 4 | Potassium. | 9 | Nitrogen, phosphorus, potassium. |
| 5 | None (Check). | 10 | None (Check). |

"Ten 4-gallon pots are very satisfactory for pot culture tests, and ½ ounce (16 grams) of dried blood, ¼ ounce (8 grams) of bone meal, and ⅛ ounce (4 grams) of potassium chloride per pot, are good amounts to use for 4-gallon pots. The plant food should be thoroughly mixed with the surface soil to a depth of about seven inches.

"Oats, barley, and spring wheat are good crops to grow in pot cultures. Garden crops may also be grown.

"For one square rod, 16 pounds of dried blood, 8 pounds of bone meal, and 4 pounds of potassium chloride are satisfactory applications, even for intensive agriculture. The plant food should be thoroughly mixed with the surface soil to a depth of about seven inches, preferably a few days before the crops are planted."

*Kinds of Crops for Plot Experiments.*—"Several different field and garden crops should be planted in rows across all of the ten plots. Oats, barley, wheat, clover, alfalfa, etc., can be planted in rows 8 inches apart, dropping the seeds about one inch apart in the row; radishes, lettuce, carrots, beets, peas, etc., in rows 16 inches apart; sweet corn, potatoes, cowpeas, soybeans, etc., in rows 32 inches apart; field corn in rows 40 inches apart, and cucumbers and melons 64 inches apart."

*Suggestions for Planting.*—"A marker with five runners 16 inches apart is easily made of boards, and it will serve to mark good straight rows across all of the plots for all crops.

"By this system of planting every crop will be represented on every plot and the effect of all of the different kinds of soil treatment can be noted on each crop."

*Local Conditions Vary.*—"In planning these soil fertility experiments, it is well to bear in mind that very sandy soil is likely to be most deficient in nitrogen. In ordinary Illinois soil, especially that which has been under cultivation for many years with clover in rotations, the element phosphorus is most deficient. In peaty soils, potassium is most deficient."

*The Practical Lesson.*—"In drawing conclusions from results which may be obtained in these experiments, it should be understood that while we may apply purchased nitrogen in order to obtain information quickly as to the needs of the soil, the nitrogen should be obtained in all general farming by the slower process of growing leguminous crops which, when provided with the proper bacteria, can get nitrogen from the air."

**Care of Plot Experiments in Vacation.**—It certainly will not be worth while to attempt plot experiments if they are to receive no care all summer. Suppose, however, that, before the school closes in June, the teacher and class plan the

work for the summer and arrange that the members of the class shall meet on the experiment fields every Saturday afternoon and give whatever attention is necessary to the crops, harvesting and caring for them at the proper time and making records of all results. If the children are interested the parents will be also, and will help and encourage them in the work. The work must be so planned and carried out that all will feel that it is *real agriculture* and *serious school work*, and the pupils should receive credit for it as for any other school work that they do successfully during the school year.

These plot experiments are especially adapted for home work. What proof of a teacher's value to his community it would be if, through the interest he had awakened in his class in agriculture, several of the pupils should undertake to conduct plot culture experiments in soil fertility and crop production on their fathers' farms at home, and at the beginning of the next school year should compare their results and conclusions with one another.

**Studies in Corn.**—Corn is America's greatest agricultural crop. Illinois is the leading corn growing state in the Union. More acreage is allotted to this crop, more money realized from it, more scientific study and interest are devoted to the production and improvement of corn than to any other product of the farm. It is a crop that is particularly well adapted to school study, both as a growing plant and as matured grain.[1]

### Exercise XXXII

*Identification of Leading Varieties of Corn.*—Get good 10-ear samples of 5 of the leading varieties of corn grown in your section of the state. Describe each variety as to (1) color of grain; (2) color of cob; (3) smoothness of surface; (4) length

[1] University of Illinois Agricultural College Extension: Studies of Corn and Its Uses.

Farmers' Bulletin, Nos. 199 and 229.

of ear (average of the 10 ears); (5) shape (tapering or cylindrical).

## Exercise XXXIII

*Questions of General Information about Corn.*—Get a half-bushel of ears of good corn. Do not select the best ears, but take them as they come from the crib.

What is the length of the longest ear?

What is the length of the shortest ear?

What is the average length of all the ears?

What is the weight of the heaviest ear?

What is the weight of the lightest ear?

What is the average weight of all the ears?

What is the greatest number of rows on any ear in the lot? What is the least number of rows? What is the average number of kernels on the largest 5 ears? Measuring one-third of the distance from the butt, what is the average circumference of the best 10 ears?

Select 5 of the best ears, 5 of the smallest ears, and 5 of the average ears. Take the weight of each ear. Shell and weigh the grain of each ear. Divide the weight of grain on each ear by the weight of the ear and express the quotients in percentages. Do the best ears give the highest percentage of grain?

## Exercise XXXIV

*Shrinkage of Corn.*—At time of husking weigh out 75 pounds of corn and put it into an open crate whose weight you know. Hang this crate of corn in a dry place where nothing can disturb it, and on the same day each week during the school year take its weight. How much weight has it lost at the end of the school year by shrinkage? During which month did it lose the most? If at husking time a farmer put 5,000 bushels of corn, counting 75 pounds per bushel, into his cribs, and it has shrunk 12% in weight during the winter, how many bushels, counting 70 pounds to the bushel, are there in the cribs June 1st?[1]

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[1] University of Illinois Agricultural Experiment Station Bulletin, No. 113.

## Exercise XXXV

*Number of Hills of Corn and the Yields per Acre.*—There are 43,560 square feet in an acre. If corn is planted in rows 3′–4″ apart each way, how many hills will there be on an acre? If each hill has 3 stalks, how many stalks will there be on an acre? If each stalk bears one ear of corn and the average weight of all the ears is 9 ounces, what will be the yield in 75-lb. bushels of corn per acre? What would be the yield if the average weight of ears was 15 ounces? What was the average weight of the ears in Exercise XXXIII?

## Exercise XXXVI

*Corn Studies in the Field.*—In a field of corn measure the width of the rows each way and compute the possible number of hills per acre. In different parts of the field select squares that should give 100 hills and count the actual number of hills growing in each square. From the average of these counts what is the number of missing hills per acre? Determine the average number of ears per hill. What percentage of the stalks are barren? Husk and weigh several 10-hill lots of corn in different parts of the field. What is the average yield of corn (in pounds and ounces) per hill? What is the average yield per stalk? At this rate what would have been the yield of corn per acre if there had been a full stand of corn with 3 producing stalks per hill?

## Exercise XXXVII

*Relation between the Tassel and the Silk.*—As soon as the silks begin to appear on the corn plants where the ears are borne get a half-dozen little paper bags and tie them over the ends of as many young ears of corn so that they will completely cover the silks. Do not remove these sacks for several weeks, not until the yellow powder (pollen) produced in the tassels, ceases to fall. Examine a young ear on another stalk when it is just "silking out." Observe that each silk is at-

tached to the place where a kernel is to be formed on the cob, a separate silk for every kernel. Also observe that great quantities of a light, yellow powder are being shed from little vessels in the tassels and that this powder is scattered by the wind over every part of the corn plants, on the ground, and even across wide fields.

**Pollination.**—The organs that produce the pollen in the tassels of corn are called *stamens*, and the silks which grow lower down on the stalk are parts of organs called *pistils*. Most of the plants with which you are familiar have the stamens and pistils growing together in the same flower, the pistil or pistils in the center of several stamens. Unless the pollen from the stamens of some plant falls upon the pistil of a flower of a plant of the same family, there can be no seed produced in that blossom. The seed is formed in the lower end of the pistil in a little sac called the *ovary*. In some kinds of plants, as in the case of corn, there are two sets of blossoms, one bearing the stamens and called *staminate* flowers, and the other containing the pistils and so called *pistillate* flowers. Of course seeds can be formed only in the pistillate flowers. In corn the tassels are staminate flowers and the silks are pistillate flowers. When the grains of pollen from the stamens of a plant fall upon the pistils of that same plant, the occurrence is called *close-pollination*, but when the pollen from the stamens of some other plant of the same variety is shed upon the pistil, the plant is said to be *cross-pollinated*.[1]

**Cross-pollination Preferred.**—Now it has been discovered that seeds produced by the process of cross-pollination show much more vigor of germination and growth when planted than do those grown by close-pollination. This is the reason why corn breeders practice detasseling every alternate row

[1] The First Book of Farming, pp. 130–135.

of corn on their breeding plots and use for seed only the ears grown on the detasseled plants where close-pollination has been impossible.[1]

## Exercise XXXVIII

*Pollination Necessary to Production.*—After a few weeks remove the paper sacks used in Exercise XXXVII and observe that no kernels have been formed on the cobs where the silks were covered. Pollination was made impossible there. You can see why so much pollen is produced, since so large a proportion of it is wasted when carried by the wind.

It is also seen how different varieties of corn "mix" when grown in the same vicinity.

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[1] University of Illinois Agricultural Experiment Station Bulletin, No. 100.

University of Illinois Agricultural Experiment Station Circular, No. 56.

## REFERENCES

THE books and bulletins named in the following lists will be found very helpful to both teachers and pupils interested in the exercises in agriculture given in this Manual.

There is no attempt to include in this list all of the good texts and reference books on agriculture. Those that are mentioned here are books with which the writer is familiar, and they treat the topics taken up in the Manual in a clear and interesting manner.

James: Practical Agriculture. D. Appleton & Co., Chicago.

Bailey: Principles of Agriculture. The Macmillan Co., Chicago.

Fletcher: Soils. Doubleday, Page & Co., New York.

Goodrich: First Book of Farming. Doubleday, Page & Co., New York.

Johnson: How Crops Grow. Orange Judd Co., Chicago.

Johnson: How Crops Feed. Orange Judd Co., Chicago.

King: The Soil. The Macmillan Co., Chicago.

Snyder: Soils and Fertilizers. The Chemical Publishing Co., Easton, Pa.

Warington: Physical Properties of the Soil. Oxford Edition. McClurg & Co., Chicago.

### BULLETINS

To obtain any of the following bulletins write to the Secretary of Agriculture, Washington, D. C. The bulletins are sent free on application.

Farmers' Bulletin No. 77: The Liming of Soils.

" " No. 111: Farmers' Interest in Good Seed.

" " No. 194: Alfalfa Seed.

Farmers' Bulletin No. 199: Corn Growing.
" " No. 215: Alfalfa Growing.
" " No. 229: The Production of Good Seed Corn.
" " No. 240: Inoculation of Legumes.
" " No. 245: Renovation of Worn-out Soils.
" " No. 253: The Germination of Seed Corn.
" " No. 257: Soil Fertility.
" " No. 266: Management of Soils to Conserve Moisture.

The following bulletins and circulars of the University of Illinois Agricultural Experiment Station will be sent free on application to the Dean of the College of Agriculture, Urbana, Ill.

Bulletin No. 76: Alfalfa on Illinois Soil.
" " 94: Nitrogen, Bacteria and Legumes.
" " 96: The Testing of Corn for Seed.
" " 100: Directions for the Breeding of Corn, etc.
" " 113: Shrinkage of Ear Corn in Cribs.
" " 99: Soil Treatment for Lower Illinois Glaciation.
" " 115: Soil Improvement for the Worn Hill Lands of Illinois.
" " 123: The Fertility in Illinois Soils.
Circular No. 56: Corn Experiments—Detasseling Corn.
" " 70: Infected Alfalfa Soil.
" " 72: Present Status of Soil Investigation.
" " 82: The Physical Improvement of Soils.
" " 96: Soil Improvement for Illinois Corn Belt.
" " 100: The "Gist" of Four Years Soil Investigation in the Illinois Corn Belt.
" " 108: Illinois Soils in Relation to Systems of Permanent Agriculture.
" " 110: Ground Limestone for Acid Soils.
Agricultural College Extension: Studies of Corn and Its Uses.

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